1974

Lubrication of the Non-Flooded Rotary Sliding Vane Compressor

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There is a great number of various types of compressors presently available. The vacuum pumps, otherwise called vacuum compressors, are automatically included, since they differ from compressors by name and the operating pressure level only. The lubrication requirements are obviously different for each type, since in some types the lubricant is recirculated, in others it leaves the compressor with the discharge gas, and in others still, it serves a dual purpose of lubrication and cooling. This discussion will, therefore, be limited to the non-flooded rotary sliding vane compressor type.

The rotary sliding vane compressor consists of a horizontal cylinder with an eccentric rotor having a series of radial slots fitted with vanes or blades and cylinder heads with antifriction bearings and shaft seals. The cylinder and heads are usually made of cast iron and have water jackets for cooling. This is the basic design. Variants may have no water jacket, inclined rather than radial blades, oil flooding, etc.

In operation the centrifugal force, acting on the blades due to the rotation of the rotor, forces the blades radially outward to continuously contact the cylinder bore and form closed pockets or cells filled with air or gas when open to the inlet port during the (nearly) half of revolution on the inlet side of the cylinder. During the second half of revolution a cell moves toward the discharge port while its volume decreases due to the progressively diminishing space between the cylinder and rotor. Thus a blade is subjected to a pressure differential between its preceding cell at a higher pressure and the following cell at a lower pressure. This pressure differential causes the blade to rub against the outer corner of the rotor slot as it slides in and out of the slot. The corner of the slot is dressed to a composite curve, but the contact with the blade is essentially a line, widened only slightly when the blade wears a concave curvature on its side. The "tip" of the blade on its long edge in contact with the cylinder wall also assumes a composite convex curvature generated by rubbing against the cylinder bore at an angle that varies with angular position, from approximately $+10^\circ$ to -10° with respect to the normal line, due to eccentricity of the rotor. The third area requiring lubrication is the bearings, usually of the straight roller type.

The two contact areas on the blade appear to have some conditions required to form an oil film, namely a wedge-shaped convergence of two surfaces, one or both of them curved. However, unlike a sleeve bearing, the rotor blade cannot develop and maintain an oil film basically due to a line contact which has no area, hence is unable to support a load. Actually the contact is somewhat wider than a line, but with a variable contact pressure distribution and far too small an area for the oil film to support loads in excess of 100 lbs. per inch of blade length, both, on the side and the tip of the blade. Possible thermal distortions of the cylinder, eventual wear patterns on the cylinder and the reciprocating motion of the blade with respect to the rotor are additional factors rendering the formation of an oil film impossible.

On the non-flood lubricated rotary the lubricant is pumped by a force feed lubricator having an adjustable capacity (in drops per minute) through tubing lines to several drilled openings in the side of the cylinder and to each bearing. In the bearing cavity a small pool of oil is maintained in which the rolling elements are dipped as they rotate. The excess is forced through a piston ring type seal (not a tight seal) into the cylinder as more oil is added to the bearing cavity.

In the cylinder the oil is spread by the blades over the inner surfaces. The cylinder is made of cast iron mainly because of its inherent surface "porosity" or roughness caused by the graphite flakes. This roughness gives the surface certain oil retention qualities, thus providing for more uniform wetting by the oil and prevents the surface from being wiped dry by the blades.

Since the formation of a continuous oil film between the parts in relative motion is not possible, there is substantial friction between the blades and cylinder wall. Friction generates heat. The portion of the heat imparted to the cylinder wall is transmitted to the water jacket.

The remainder is absorbed by the blade. For this reason the blades are made of composite plastic materials having low coefficients of friction and good resistance to abrasion. These materials are poor heat conductors and, therefore, the rubbing tip of the blade is subjected to localized temperatures higher than those of other parts or the gas being compressed. The lubricant in contact with the rubbing portions of the blade is also subjected to these higher temperatures.

Elevated temperatures have an adverse effect on petroleum oils, causing them to break down and form carbon and varnish deposits. In the case of an air compressor the air at elevated temperatures (approximately 350°F) tends to oxidize the oil. The atmospheric humidity condensed in the intercooler (on two-stage compressors) tends to wash out the oil, emulsify it and thus change its properties and possibly react with some of the additives. In the case of a gas compressor, some of the heavy hydrocarbons may condense into liquids in proximity of the cooling water jackets and dilute the oil. This dilution is especially serious in the bearing cavities where the oil dwells for a longer time than in the cylinder. Being diluted, it no longer has the proper viscosity for sufficient lubrication. In other cases, the gas may be acidic in nature or the intake air may be laden with acid fumes or other pollutants defying simple filtration.

These then are some of the conditions under which oil must provide lubrication in a rotary compressor. The above should also serve to indicate why the oil may not be reclaimed and reused having been subjected to high temperatures and moisture. It is also evident that under these varying conditions it is not practical to develop a general rule for the quantity of lubricant to be used. The manufacturer's recommendations should, therefore, be followed closely.

GENERAL RECOMMENDATIONS:

To provide lubrication, the oil must have suitable formulation for a particular application and correct viscosity at the operating temperature. For non-flooded rotary compressors, in cases where the oil is not affected by the gas or vapors handled, the viscosity should be approximately 40 to 50 SSU AT THE OPERATING TEMPERATURE which is considered to be the gas discharge temperature. Napthenic base oil is preferred due to formation of less abrasive carbon deposits, if any.

The various compressor gas applications may be grouped according to similarity of conditions and thus the oil formulation may be generalized to a degree.

AIR:

Generally a detergent type oil should be used, at least meeting or exceeding the MIL-L-2104A, Supplement 1 specifications. The detergent additives are required to dissolve and scrub out any carbonized or varnished oil deposits caused by high temperature. Other additives are desirable, especially the anti-oxidants and anti-wear additives. Other desirable properties are a high flash point and a low pour point. For outdoor locations or outdoor air intake in cold weather a correspondingly lower viscosity oil should be used than specified for warm weather periods.

REFRIGERATION SERVICE:

Most oil suppliers have a special group of products for this service. These oils are usually of napthenic stock to have low pour and wax haze points and a minimum of additives, usually only an anti-oxidant. The oil must have proper viscosity for the operating temperature, i.e. SAE 20 grade below 230°F and SAE 30 for discharge temperatures of 230 to 300°F. The higher viscosity SAE 30 oil has a higher pour point and is more difficult to separate from the refrigerant. It is, therefore, usually avoided by the operating personnel at any cost. The cost often is, however, accelerated internal wear and possible damage to the compressor.

WET SERVICE:

Steam condenser, pump priming and rotary filter service vacuum pumps are in this group as well as two-stage compressors in localities with high atmospheric humidity. Here the detergent oil, as for air service, is the best choice. Where discharge temperatures are continuously below 250°F a non-detergent oil may be used, but it must be "polar compounded". This gives the oil improved wetting qualities of the lubricated surfaces in presence of moisture.

CORROSIVE AND ACIDIC GAS SERVICE:

Since this group covers a great variety of chemically active gases and vapors, only a limited generalization can be made. In this service the gases may be corrosive to the materials of construction as well as render the oil acidic. Therefore, the bearing cavities, where the oil remains for a longer time than in the cylinder, should be sealed against circulation of the gas through them, to protect the bearings from corrosion. Small quantities of corrosive components of the gas handled can be successfully coped with by a highly detergent oil which meets or exceeds MIL-L-2104B specifications. Lubrication for highly corrosive applications must be recommended individually by the compressor manufacturer.

HYDROCARBON GAS SERVICE:

In this group are various refinery and oil field applications, storage tank vapor recovery, chemical plant service, etc. For natural gas, butane and light simple hydrocarbons, a detergent oil is used. Pentane and heavier hydrocarbons have relatively high boiling poing temperatures which can cause them to condense in contact with water cooled cylinders, especially in the bearing cavities. This condensate mixes with the oil and dilutes it. Therefore, a heavier (higher viscosity) oil than warranted by the operating temperature should be used, i.e. SAE 40 where SAE 30 would normally suffice. For such cases the compressor should also have provisions to reduce the circulation of gas through the bearing cavities.

Heavy hydrocarbons also have low K-values (ratio of specific heats). Consequently, the discharge temperatures are not very high and for handling simple paraffins the oil need not have detergent additives. But in the case of sour gases, with significant concentrations of hydrogen sulfide, sulphur dioxide or mercaptans, and in the case of mixtures other than simple formula gases, particularly the polymerizing varieties, the detergent oil is a must, to counteract the acids or to dissolve and remove the hard, abrasive products of polymerization.

SYNTHETIC LUBRICANTS:

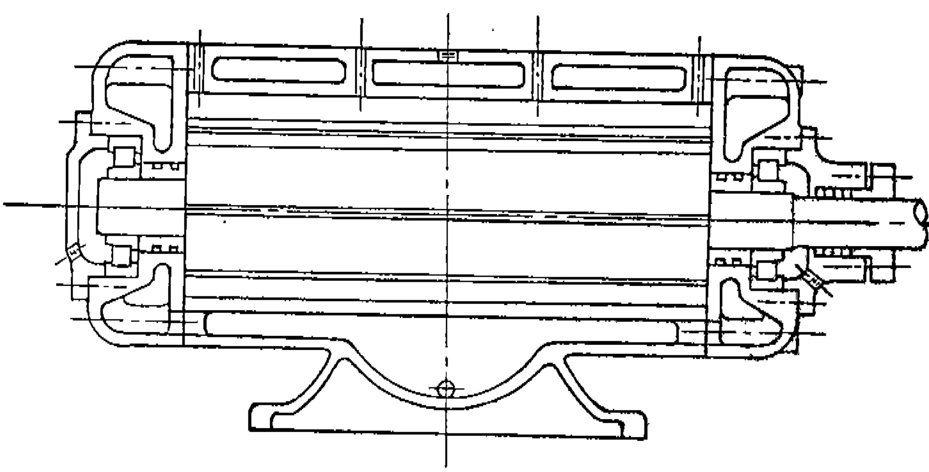
There is at the present time a considerable assortment of synthetic lubricants available, such as phosphate esters, halogenated ethylenes and ethers, glycols and fluorosilicones. Their main use is as hydraulic fluids to minimize fire hazard. They are also used as compressor lubricants (must have proper viscosity), to minimize fire and explosion hazards, provided, they are not objectionable from the standpoint of process gas contamination. Higher cost is still a factor.

Some synthetic oils are detrimental to paint, gasket materials or plastic parts, hence the compressor will usually require some preparation to convert from oil to a synthetic lubricant, as recommended by the manufacturer. Generally, the synthetics may not be mixed with petroleum oils, although some are used as additives. Certain synthetic lubricants are used for compressor lubrication because of their specific qualities such as solubility in water for easier removal from compressed air in scrubbers, clean burning in gas turbines (no carbonization), control of bacteria growth in compressor air systems in presence of moisture, etc.

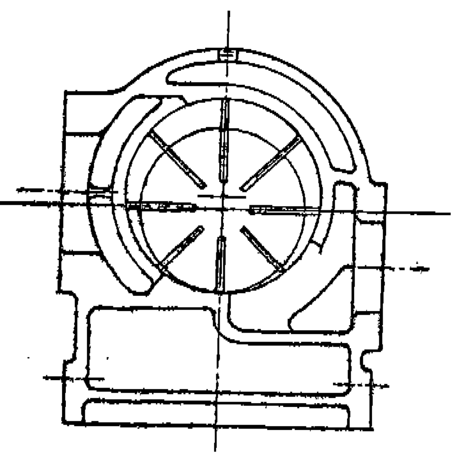
For a good lubrication analysis the following information should be ascertained and considered in selection of the lubricant.

1. The discharge pressures of each stage. They determine the discharge temperature.
2. Type of gas handled, its degree of purity, amount of contaminants, if any.
3. Humidity and seasonal temperatures in case of air.
4. Whether outdoor location is in cold climate. A heater may be needed in the lubricator.
5. Chances of condensation of the gas handled within the compressor or intercooler.
6. Chances of liquid spillover into the compressor (a typical problem in refrigeration and petrochemical service).
7. Changes in the gas handled due to increase in temperature or pressure (such as polymerization of butadiene).
8. Anything else that may mix, react with or affect the lubricant.

Although the above grouping of service makes it possible to determine the general characteristics of the lubricant, each individual application may have many of its own, apparently insignificant circumstances which may affect the choice of lubricant. It is, therefore, most important to make them known to the compressor manufacturer so that the correct lubricant may be specified for trouble-free operation.



ROTARY COMPRESSOR
LENGTHWISE SECTION



ROTARY COMPRESSOR
CROSS SECTION